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F02D 41/14

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U1S S1990 S2181

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US 4655182 A

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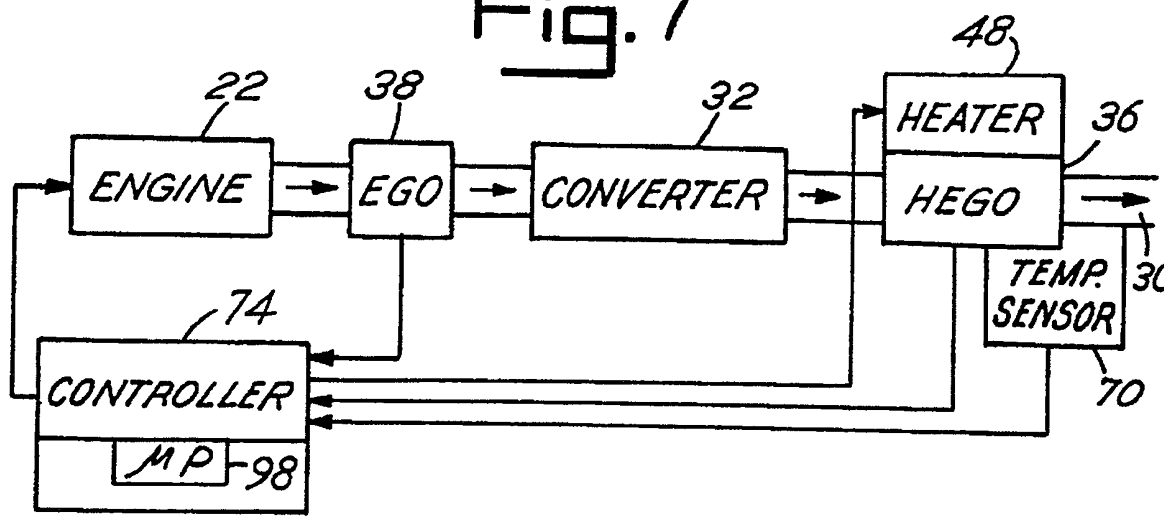
(54) Multiple exhaust gas oxygen sensor system for IC engine with catalytic converter

(57) The internal combustion engine 22 has an exhaust conduit 30, a catalytic convertor 32 and exhaust gas oxygen sensors 38, 36, upstream and downstream respectively of the catalytic convertor 32. An engine parameter controller 40 receives inputs from both the upstream and downstream oxygen sensors (38, 36). A temperature sensor 70 is associated with the downstream sensor 36 and the controller (40) may activate a heater 48 to warm up the downstream oxygen sensor 36 when the temperature sensor informs the controller 40 that the temperature of the downstream sensor has fallen outside a predetermined operating range.

The heater may be powered by a signal of variable duty cycle. The controller may rely on the signal from the upstream sensor 38 when both oxygen sensors have a dynamic output and on the signal from the downstream sensor when both sensors emit steady state signals.

Fig. 7



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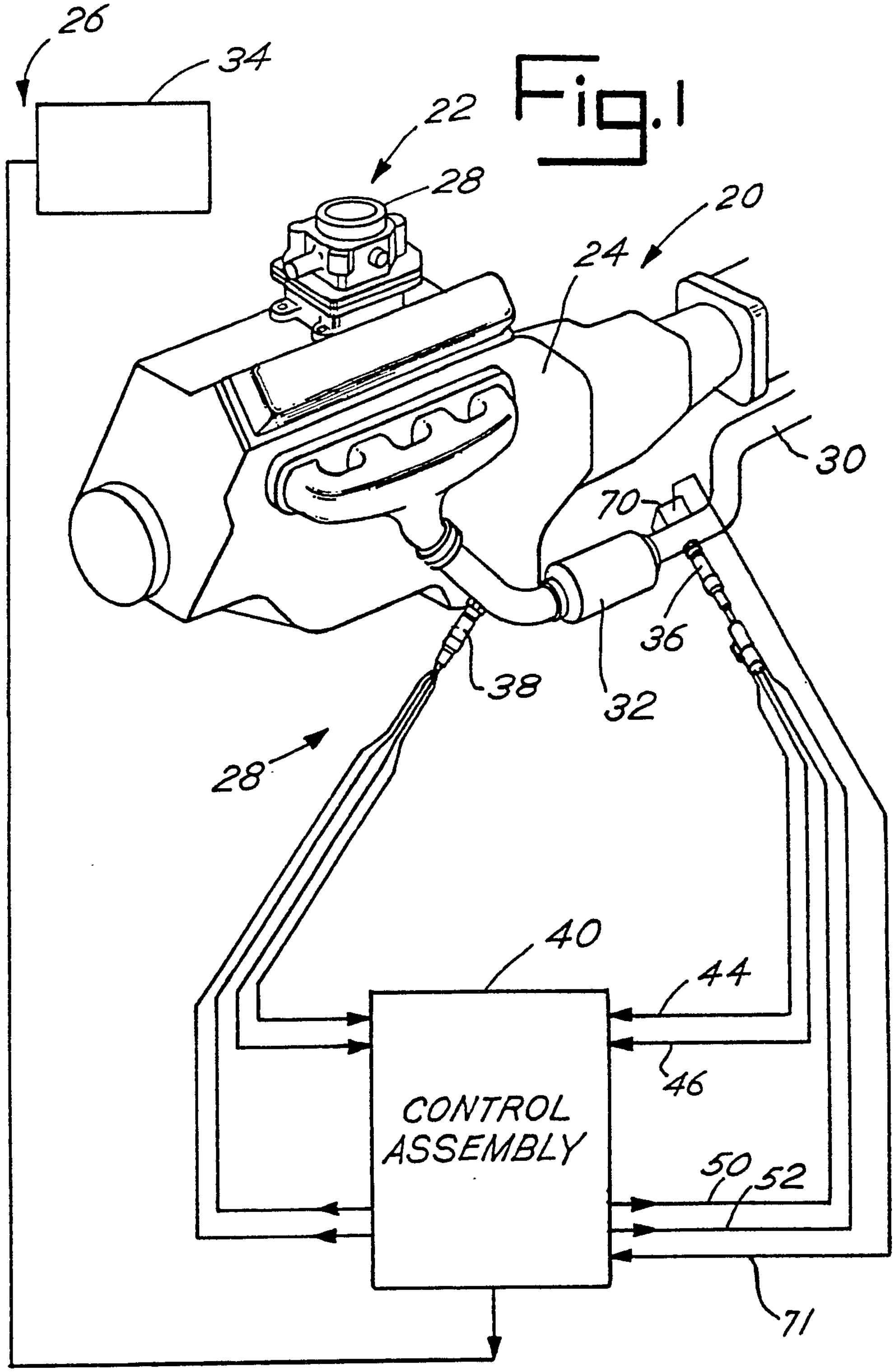


Fig. 1
26
34
22
28
20
24
30
70
36
38
32
28
40
44
46
CONTROL ASSEMBLY
50
52
71

Fig. 2

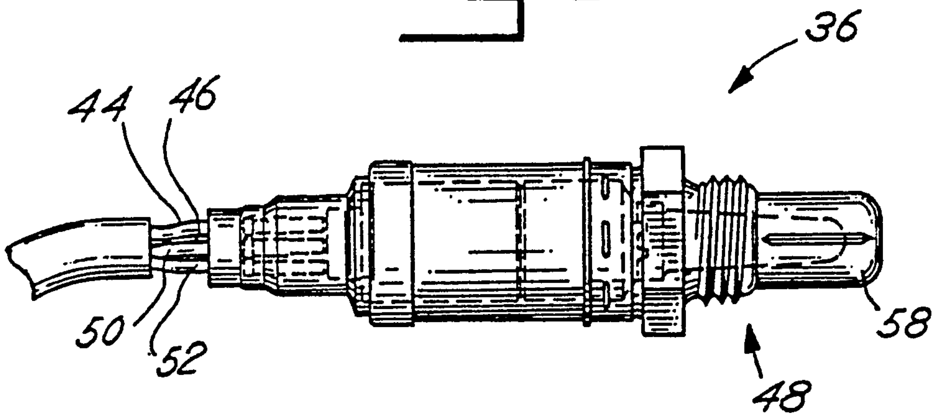


Fig. 3

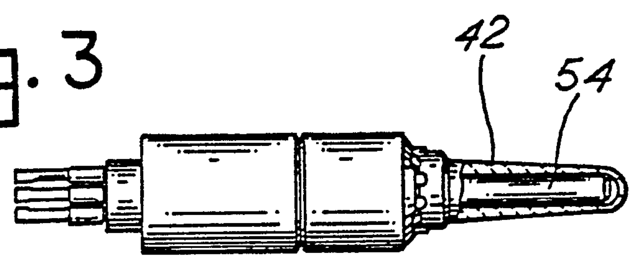


Fig. 4

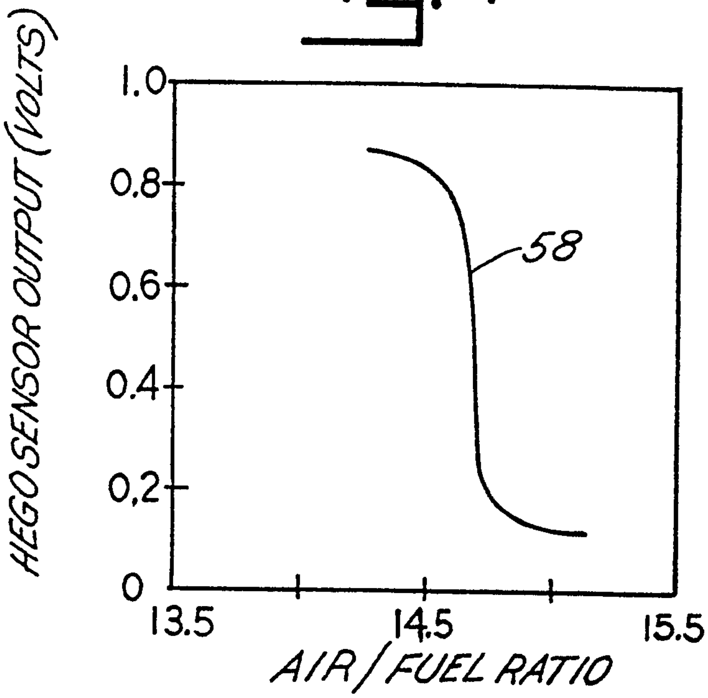

HEGO SENSOR OUTPUT (VOLTS)
1.0
0.8
0.6
0.4
0.2
0
58
13.5
14.5
15.5
AIR/FUEL RATIO

Fig. 5

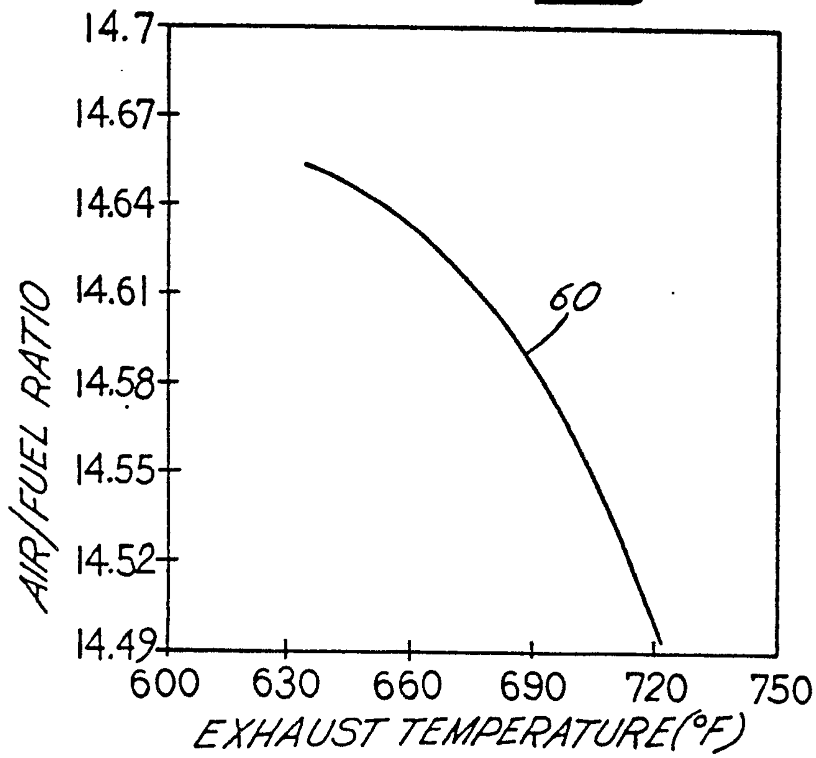

AIR/FUEL RATIO
14.7
14.67
14.64
14.61
14.58
14.55
14.52
14.49
60
600
630
660
690
720
750
EXHAUST TEMPERATURE(°F)

Fig. 6

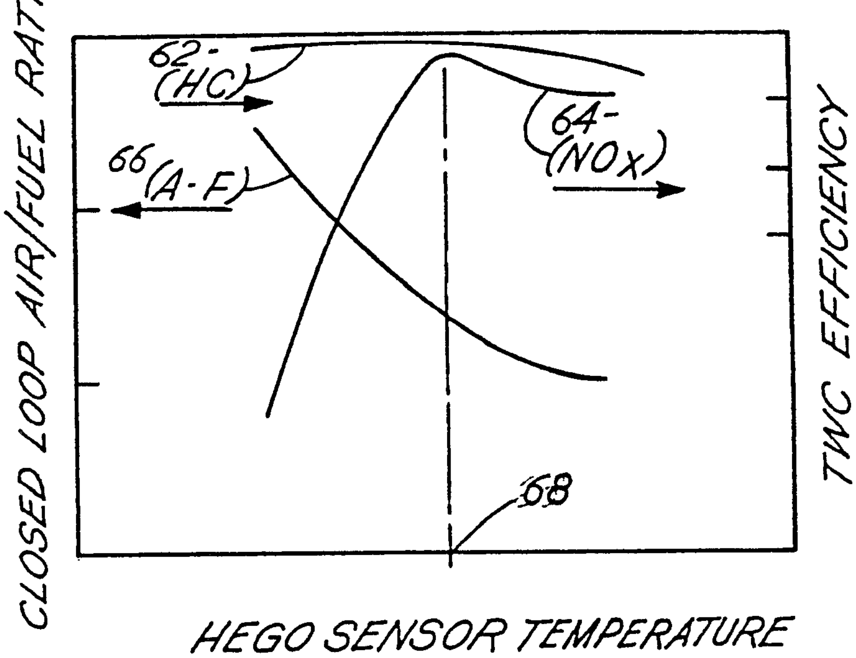

62-
(HC)
66
(A-F)
64-
(NOx)
68
CLOSED LOOP AIR/FUEL RATIO
TWC EFFICIENCY
HEGO SENSOR TEMPERATURE

Fig. 7

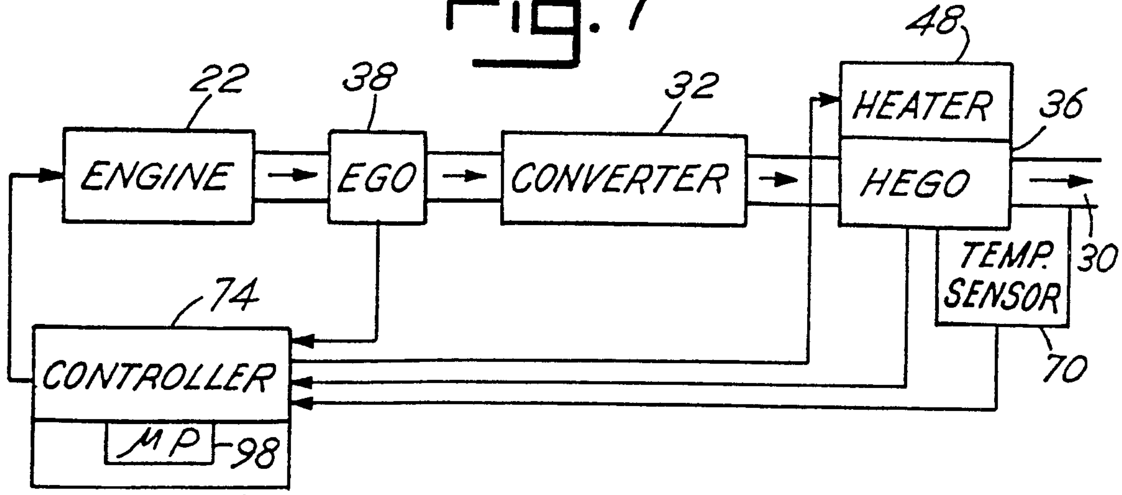


Fig. 8

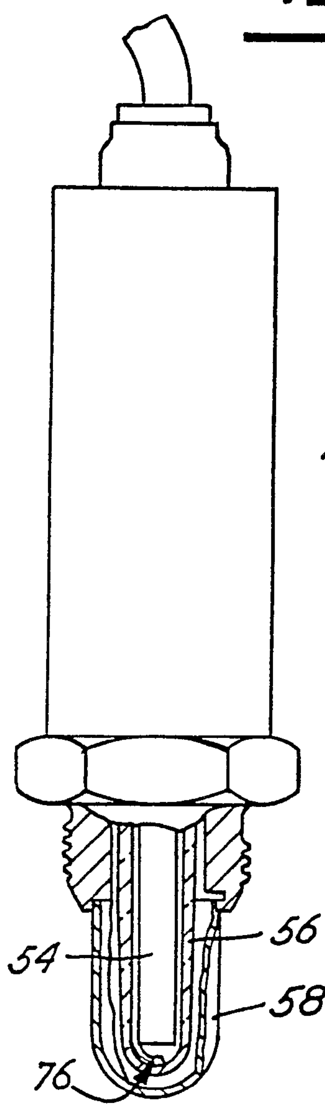


Fig. 9

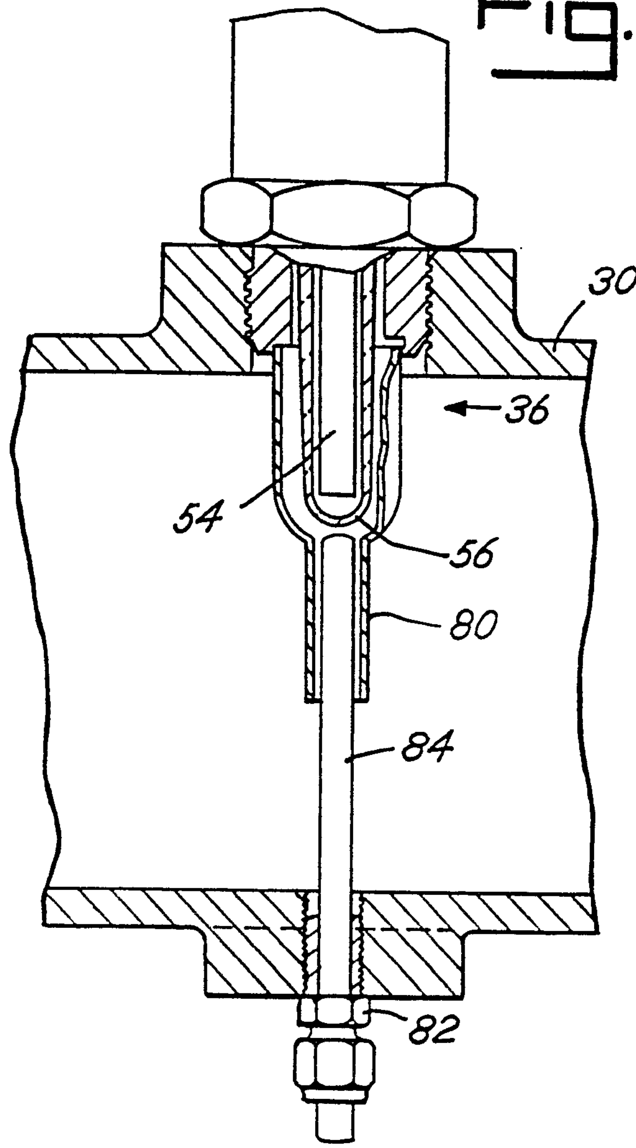


Fig. 10

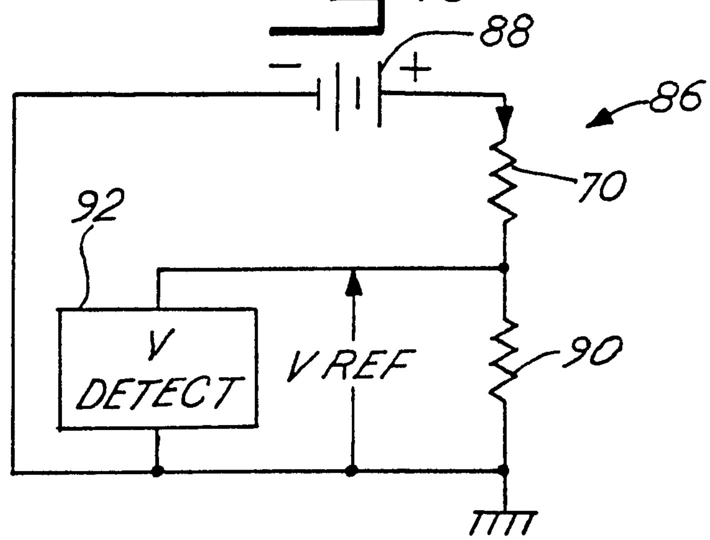

88
−
+
86
70
92
V
DETECT
V REF
90

Fig. 11

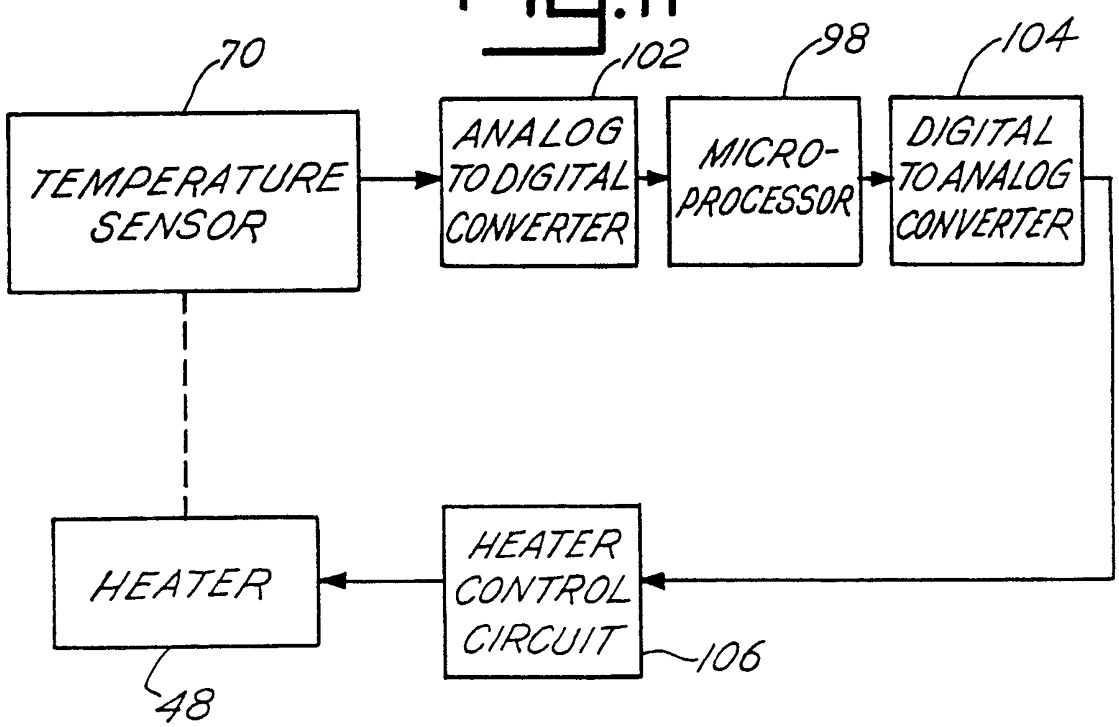

70
TEMPERATURE
SENSOR
102
ANALOG
TO DIGITAL
CONVERTER
98
MICRO-
PROCESSOR
104
DIGITAL
TO ANALOG
CONVERTER
HEATER
48
HEATER
CONTROL
CIRCUIT
106

Fig. 12

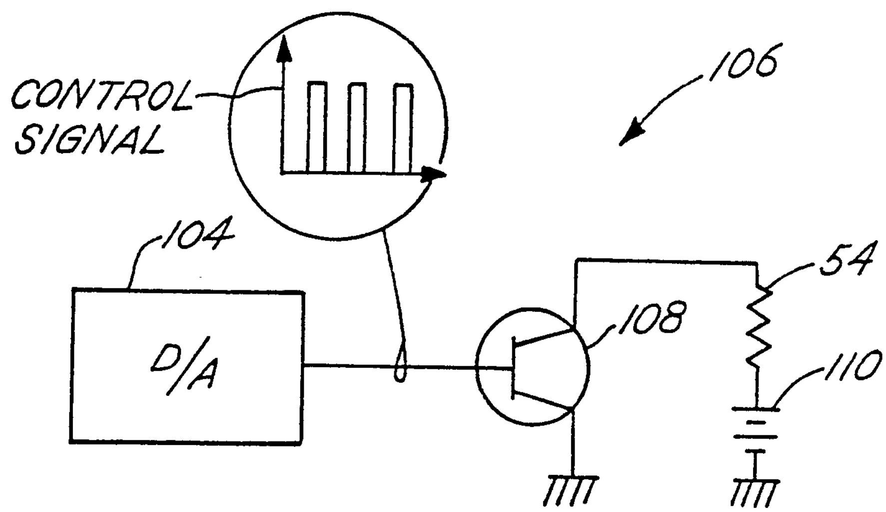


Fig. 13

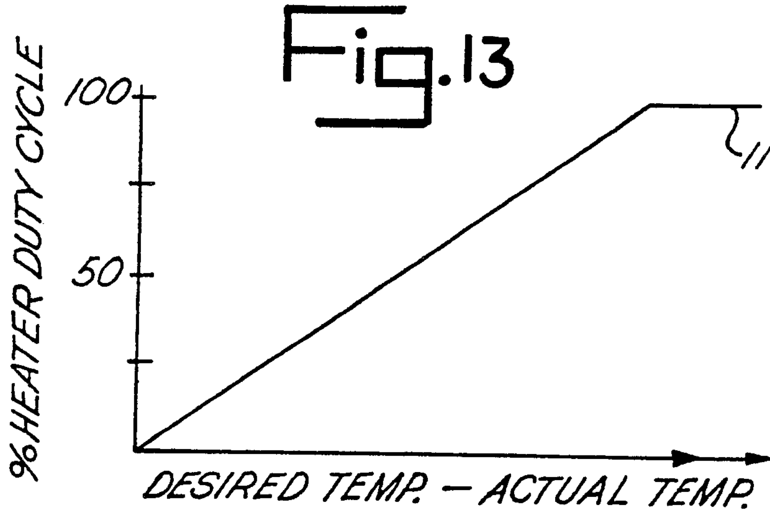
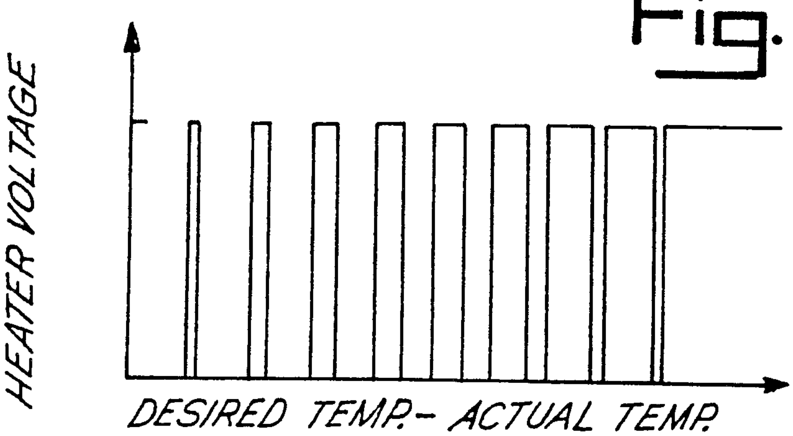


Fig. 14



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MULTIPLE OXYGEN SENSOR SYSTEM FOR AN ENGINE

The present invention relates generally to electronic engine controls and to feedback controls for engine operation using exhaust gas oxygen sensors. More particularly, the present invention relates to a sensor system having multiple exhaust gas oxygen ("EGO") sensors interconnected to an exhaust system both upstream and downstream of a catalytic converter.

Many automotive vehicles include an internal combustion engine and an exhaust system that provides a conduit for heated combustion gas to move away from the engine. The temperature of the exhaust gas ranges from ambient temperature, when the engine has not been in operation recently, to 400° Celsius or more.

A typical exhaust system may include an EGO sensor assembly and a catalytic converter. The catalytic converter promotes the conversion of hydrocarbons, carbon monoxide, and oxides of nitrogen into less noxious compounds. An EGO sensor is often placed "upstream" of the catalytic converter. The terms "downstream" and "upstream" are relative terms used to denote relative positions along the exhaust conduit, or pipe, of the vehicle. The term "downstream" refers to positions along the exhaust conduit that are reached by a particle in the exhaust gas later in time than positions that are "upstream."

Many air-fuel control systems in presently available vehicles, with the EGO sensor located upstream of the catalyst, provide an air-fuel feedback signal for a closed-loop air-fuel delivery system in the engine. The upstream EGO sensor, however, can be "poisoned" by certain compounds, such as lead or silicone. Such components may be present in the raw exhaust gas. This may occur, for example, if a motorist improperly uses "leaded" gasoline in an engine designed only for "unleaded" gasoline. Such poisoning may render the EGO sensor ineffective in accurately ascertaining the level of the oxygen concentration in the exhaust gas.

Also, the output characteristics of an upstream EGO sensor may change over time. Moreover, under some operating conditions, the upstream EGO sensor may be unable to bring the exhaust gas flowing nearby it to a substantial equilibrium. Such conditions may be dependent on, for example, the engine load and cylinder-to-cylinder air-fuel maldistribution in the engine. As a result, the EGO sensor will exhibit "offset errors."

Further, many EGO sensors only operate effectively if the temperature of the sensor is within a particular range. The temperature of the sensor is, of course, influenced by the temperature of the adjacent exhaust gas. To assist an EGO sensor to make accurate measurements over a wide range of exhaust gas temperatures, the EGO sensor assembly often includes an electric heater physically adjacent, or near, the EGO sensor. Such a heated exhaust gas oxygen sensor is a type of EGO sensor and is often referred to as a HEGO sensor. When actuated, the heater warms the sensor to enable it make more accurate measurements and, thus, reduce the effect of temperature variations of the exhaust gas passing through the exhaust pipe of the vehicle.

Prior art systems exist for controlling the air-fuel ratio of an internal combustion engine. For example, U.S. Patent No. 4,708,777, issued to Kuraoka, discloses an air/fuel ratio feedback control system that is responsive to an EGO sensor. The EGO sensor is maintained at a predetermined temperature by feedback from the sensor heater.

Thus, some prior systems have attempted to maintain a constant air-fuel ratio operating point, which is independent of the exhaust gas temperature. In addition to maintaining a constant, closed-loop air-fuel ratio operating point independent of exhaust gas temperature or engine operating conditions, however, it is also desirable to have an EGO sensor that may more accurately detect oxygen levels, regardless of the exhaust gas constituencies and poisoning effects. Simultaneously, it is also desirable to have a system in which the oxygen level is detected promptly, so as to lower the reaction time of the air-fuel controller. In this way, the feedback control enables the controller to more precisely regulate the operation of the internal combustion engine.

Further, since the EGO sensor assemblies are generally mass-produced and put on many cars, even a small savings on one part of the assembly can accumulate to a substantial annual savings. Thus, an EGO sensor system should not have an excessive number of parts nor high manufacturing costs. Moreover, it is important that the sensor assembly be reliable.

The present invention is an EGO sensor system for an internal combustion engine. The engine has an exhaust conduit and a catalytic converter on the conduit, downstream of the engine. The system includes an oxygen sensor upstream of the catalytic converter, an oxygen sensor downstream of the catalytic converter, and a controller. The controller receives signals from the upstream and downstream oxygen sensors indicating, respectively, the upstream and downstream oxygen levels. The controller then responsively provides a control signal that may be used by the engine to adjust operating parameters, such as the air-fuel mixture provided to the engine.

In another embodiment, the present invention is a method for providing an oxygen level signal to an air-fuel mixture controller for the internal combustion engine. The method includes the steps of detecting the downstream oxygen level, detecting the upstream oxygen level, and providing a controlled signal to the fuel distribution system based upon the upstream and downstream oxygen levels.

The invention will now be described further, by way of example, with reference to the accompanying drawings, in which:

FIGURE 1 is a diagram of an oxygen sensor system interconnected to the exhaust system of an internal combustion engine;

FIGURE 2 is a side view of the HEGO sensor assembly shown in FIGURE 1;

FIGURE 3 is a partial cross-sectional view of the HEGO sensor assembly shown in FIGURE 2;

FIGURE 4 is a graph showing the experimentally measured output voltage of the HEGO sensor assembly shown in FIGURE 1 as a function of the engine's air-fuel ratio;

FIGURE 5 is a graph showing the experimentally measured control points of the HEGO sensor assembly shown in FIGURE 1 as a function of the exhaust gas temperature;

FIGURE 6 is a graph showing the experimentally measured changes in the conversion efficiency of the catalytic converter shown in FIGURE 1 and in the engine's closed loop air-fuel ratio as a function of temperature;

FIGURE 7 is a schematic diagram of a preferred embodiment of the invention shown in FIGURE 1;

FIGURE 8 is a partial cross-sectional view of a combined HEGO sensor and temperature sensor that may be used with the invention shown in FIGURE 7;

FIGURE 9 is a partial cross-sectional view of an alternative HEGO sensor and temperature sensor that may be used with the invention shown in FIGURE 7;

FIGURE 10 is a schematic diagram of a temperature sensor that may be used with the invention shown in FIGURE 7;

FIGURE 11 is a schematic diagram of an apparatus for driving the sensor heater shown in FIGURE 1;

FIGURE 12 is a schematic diagram of a preferred embodiment of the heater control circuit shown in FIGURE 11;

FIGURE 13 is a graph showing the variation in heater duty cycle as a function of the difference between desired and actual temperature of the oxygen sensor shown in FIGURE 1; and

FIGURE 14 is a graph of a duty cycle for the heater shown in FIGURE 1, when the actual temperature of the sensor is decreasing with respect to the desired temperature.

Referring to Figures 1-14, a preferred embodiment of the present invention is shown as an oxygen sensor system with signal correction 20 for use with an internal combustion engine 22. As shown in Figure 1, the engine 22 includes an engine block 24 having internal cylinders (not shown) in which combustion takes place, an air-fuel delivery system 26, and an exhaust system 28.

The exhaust system 28 includes an exhaust pipe or conduit 30, to carry exhaust gas away from the engine 22, and a three-way catalytic converter 32. In the one exemplary embodiment shown, the air-fuel delivery system 26 includes an air-fuel distributor 34 and the oxygen sensor system 20. The sensor system 20 includes a downstream HEGO sensor 36, which is downstream both the engine 22 and the catalytic converter 32, an upstream HEGO sensor 38, which is upstream of the catalytic converter 32 (but, of course, downstream of the engine 22), and a HEGO control assembly 40. The air-fuel distributor 34 receives a signal from the control assembly 40 and physically provides a mixture of air and fuel to the engine cylinders.

Each of the HEGO sensors 36, 38 includes similar components, and the downstream sensor 36 is explained in order to illustrate the basic operation of both. The sensor 36 includes a sensing tip 42, interconnected to first and second output leads 44, 46, and a heater 48, also having first and second leads 50, 52. See Figures 1-3. The leads 44, 46 deliver an oxygen level signal to the control assembly 40 (representing the oxygen concentration in the exhaust gas adjacent the sensing tip (42).

The first and second leads 50, 52 of the heater 48 are interconnected to a resistive heating element 54. The sensing tip 42 is encased in a protective canister 58, and the assembly is screwed into the exhaust pipe 30. The sensing tip 42 contacts gas flowing through the exhaust pipe 30, effectively measures the level of oxygen in the exhaust gas, and provides an oxygen level signal, in the form of a voltage differential, along the output leads 44, 46. The tip 42 is typically composed of zirconia dioxide ZrO_2.

The control assembly 40 receives the oxygen level signals from the upstream and downstream EGO sensors 36, 38. In response, the assembly 40 provides an air-fuel mixture control signal to the air-fuel distributor 34, which, in turn, influences the richness or leanness of the air-fuel mixture supplied to the cylinders of the engine 22.

The downstream HEGO sensor 36 acts as a feedback unit. The sensor 36 is effectively "protected" by the catalytic converter 32: the exhaust gases are brought to substantially chemical equilibrium by the catalytic converter 32 before reaching the downstream sensor 36 (and the catalytic converter 32 prevents contaminants, such as lead, from reaching the downstream sensor 36). As a result, the air-fuel offset errors are reduced. Thus, the sensor 36 is able to bring the chemicals in the exhaust gas near it into equilibrium, and the downstream sensor 36 provides a signal more precisely representing the oxygen level concentration in the exhaust gas.

The upstream sensor 38, in contrast, provides a signal that more quickly responds to changes in the chemical make-up of the exhaust gas. However, while the dynamic response is faster than that provided by the downstream sensor 36, the upstream sensor 38 is not "protected" by the catalytic converter 32 and may produce signals subject to offset errors.

Accordingly, the control assembly 40 receives signals from both upstream and downstream sensors 38, 36. When there is a substantial change in the exhaust gas composition, both the upstream and downstream sensors 36, 38 tend to change the oxygen level signals they provide. In response to such dynamic signals, the control assembly 40 promptly adjusts the mixture control signal so that it substantially corresponds to the changed signal from the upstream sensor 38. As the downstream sensor 36 then reacts to the change in composition of the exhaust gas, the control assembly 40 may then further modify the mixture control signal supplied to the air-fuel distributor 34 in accordance with the downstream sensor's signal. As both the upstream and downstream sensor signals substantially reach a steady state condition, the controller 40 "tunes" the mixture control signal so that it substantially corresponds to the slower, but generally more accurate, signal provided by the downstream sensor 36.

Thus, in many cases, the downstream sensor 36 provides a more precise representation of the exhaust gas oxygen concentration (albeit with a slower response time) than the upstream sensor 38. However, variations in the temperature of the downstream sensor 36 may substantially affect the accuracy of the signal it provides. Accordingly, the heater 48 warms the sensor 36 and reduces effects of exhaust gas temperature variations. A heater may also be positioned to warm the upstream sensor 38, as required.

The leads 50, 52 deliver, from the control assembly 40 to the heater 48, an electric power signal to activate the heater 48. The control assembly 40 selectively activates the heater 48 of the sensor 36 to maintain the sensor 42 within a proper temperature range.

The graph 58 of Figure 4 shows a typical oxygen level signal provided by the HEGO sensor 38 as a function of the air-fuel ratio being delivered by the system 26 to the engine 22. The sensor 36 provides a substantially high voltage, in excess of 0.8 volts, when the air-fuel ratio is below 14.5, but provides a low voltage, substantially below 0.2 volts, when the air-fuel ratio is above 15. Thus, a relatively small change in air-fuel mixture causes a dramatic change in the sensor voltage (or the "oxygen level signal").

Often, the output of the sensor 36 is processed by a comparator within the controller 40 before being passed to the air-fuel delivery system 34. The signal provided by the comparator may be either (1) a large value (or "one") or (2) a low value (or "zero"), depending on whether the HEGO sensor voltage is greater or less than a reference "set point" (or "control point") voltage, such as, for example, 0.45 volt.

Many air-fuel control systems using an EGO or HEGO sensor as the feedback element have a tendency to control to an air-fuel ratio that is too high (too "lean") when the temperature of the exhaust gas is too low. Conversely, the controlled air-fuel ratio may be too low (too "rich") when the sensor has been heated above its operating range.

For example, the graph 60 of Figure 5 shows experimentally derived data regarding how the sensor's closed loop control point varies as a function of the exhaust gas temperature. An exhaust temperature change of less than 100° F. causes the control point to change well over 0.1. Thus, for example, the oxygen sensor 36 and control assembly 40 may regulate the air-fuel ratio of the engine 22 to 14.65 when the exhaust temperature is approximately 640° F., but to an air-fuel ratio of 14.56 when the exhaust temperature is approximately 700° F.

The change in set point--the designation by an oxygen sensor assembly of what air-fuel mixture is appropriate--may have a substantial effect on the operation of the engine 22. Figure 6 shows experimentally derived data for a catalytic converter's efficiency in converting hydrocarbons and oxides of nitrogen and the closed-loop air-fuel ratio as a function of temperature. Line 62 shows the converter's efficiency in converting hydrocarbons, and line 64 shows the converter's efficiency in converting oxides of nitrogen, as the temperature and, consequently, the air-fuel ratio 66 vary. Only the air-fuel mixture near a particular balance 68 point provides the substantially optimal efficiency in reducing hydrocarbons and oxides of nitrogen.

Thus, precisely maintaining the air-fuel mixture is important to keep the converter 32 operating efficiently. Providing a correct oxygen level concentration signal to system 34 is important, so that the correct air-fuel ratio can be maintained. The oxygen level signal provided by the oxygen sensor 36 can have substantial impact on the air-fuel ratio and thus on the operation of the fuel distribution system 34 and the efficiency of the catalytic converter 32.

As shown in Figures 1 and 7, a preferred embodiment of the present invention includes a temperature sensor 70 inside the downstream sensor 36. The temperature sensor 70 provides a temperature level signal to the control assembly 40 via one or more leads 71. The control assembly 40 includes a microprocessor 72, which receives inputs from the downstream and upstream sensors 36, 38, and the temperature sensor 70, and responsively provides a controlled signal to the engine 22 and an activating signal to the heater 54 inside the downstream sensor 36.

Figure 8 shows one embodiment of the temperature sensor 70. The temperature sensor 70 consists of a thermocouple 76 located adjacent the sensor tip 56, inside the canister 58. Under this arrangement, the thermocouple 76 provides an accurate temperature level signal to the control assembly 40 regarding the operating temperature of the adjacent sensing tip 56.

Another embodiment of the temperature sensor 70 is shown in Figure 9. The temperature sensor 70 consists of an extension tube 80 which mounts over the tip of the sensor 36, a compression fitting 82 in the exhaust pipe 30, and an elongated thermocouple 84, which fits between the extension tube 80 and fitting 82. Again, the thermocouple 84 provides an electrical output that depends on the surrounding temperature. The compression fitting 82 and tube 80 hold the thermocouple 84 in place in the exhaust pipe 30, adjacent the tip 56 of the sensor 36.

Yet another apparatus 86 to detect the temperature adjacent the sensor 36 is shown in Figure 10. The apparatus 86 consists of a known voltage source, such as an automotive vehicle battery 88, connected in series with the heater 70 and a known resistance 90, together with a voltage detector 92. The heater 70 and known resistance 90 thus divide the voltage provided by the automotive battery 88. The voltage measured by the detector 92 across the known resistance 90 is substantially directly proportional to the resistance of the heater 70. The resistance of the heater 70 has been found to reflect the temperature of the sensor 36. Accordingly, the control assembly 40 may receive a signal from the voltage detector 92 that is indicative of the temperature of the sensor 36. Notably, however, if the vehicle battery 88 is chosen as the voltage source, the temperature associated with a particular resistance is a function of battery voltage.

In yet another embodiment of the present invention, rather than using a direct measurement of the temperature of the sensor 36, the control assembly 40 receives inputs regarding engine variables, such as speed and load. From this, and the length of time that the engine 22 has been in operation, the microprocessor 72 may "map" the inputs regarding the experienced engine parameters with tables in its memory to estimate the expected temperature of the sensor 36.

The voltage output of the thermocouple 76, 84 may be converted to a digital signal proportional to temperature and read by the microprocessor 72 within the control assembly 40. In the microprocessor 72, the sensor temperature is compared to the desired temperature. If the actual and desired temperature differ, the actuating signal is provided to the heater 48. The activating signal may increase or decrease the duty cycle of the current supplied to the heater 48. As a result, the actual sensor temperature is regulated and may be maintained within a desired range.

An apparatus 100 for controlling the current to the heater 48 is shown in Figure 11. The signal from the temperature sensor 70 is supplied to an analog to digital converter 102, which then supplies an output to the microprocessor 72. The microprocessor 72 provides an output to a digital to analog converter 104, which provides a control signal to a heater control circuit 106. The heater control circuit 106 turns the heater 48 on and off pursuant to a prescribed duty cycle, which, in turn, influences the temperature sensed by, and the analog output of, the temperature sensor 70.

The heater control circuit 106 is shown in Figure 12. The control circuit 106 includes a switching transistor 108 in series with the automotive battery 88 and the heating element 54. The analog signal provided by the digital to analog converter 104 to the switching transistor 108 turns the transistor 108, and thus the heater 48, on and off as required.

Representations of the control signals supplied to the switching transistor 108 are shown in Figures 13 and 14. The microprocessor 72 detects, from the temperature sensor output, when the actual temperature of the sensor 36 is less than the desired temperature. If the actual temperature is substantially equal to (or above) the desired temperature, substantially no signal is applied to the switching transistor 108. If the actual temperature is only slightly lower than the desired temperature, the switching transistor 108 is turned on a small portion of the time. If the actual temperature is substantially lower than the desired temperature, the switching transistor 108 has a longer duty cycle.

A graph 110 showing the relationship between (1) the duty cycle of the transistor 108 and heater 48 voltage and (2) the difference between the desired temperature and the actual (measured) temperature is shown in Figure 13. As indicated in Figure 13, the heater 48 voltage is kept on continuously when the difference between the desired operating temperature of the sensor 36 and the actual temperature of the sensor 36 (as measured by the temperature sensor 70) exceeds a predetermined quantity. An exemplary graph of the duty cycle of the heater 48 is shown in Figure 14, where the temperature of the sensor 36 continues to drop below the desired operating temperature.

Thus, the temperature sensor 70 provides feedback to the control assembly 40 to keep the downstream sensor 36 within a predetermined temperature range. The same feedback system may also be used, of course, with a heater associated with the upstream sensor 38, to keep the temperature of the sensor 38 within a predetermined range or "window."

The advantage of using the temperature sensor to avoid offsets of the downstream HEGO sensor 36 is that such a system makes the operation of the downstream sensor 36 relatively impervious to changes in the battery voltage, differences in heater resistance (between different heaters), or in the exhaust gas temperature. Moreover, such a method does not suffer from the offset errors associated with open loop adjustment schemes.

Further, in some applications, the control assembly 40 may receive one or more inputs regarding, for example, the engine speed, the load placed on the engine, coolant temperature, ambient temperature, length of time of engine operation, and/or the oxygen level sensor temperature that suggest that the oxygen level signal provided along the leads by the downstream sensor 36 is in error and should be adjusted upward or downward. The control assembly 40 may then adjust the activation of the heater 48, such that the sensor 36 becomes warmer or cooler, and the output of the sensor 36 is thus adjusted (as a result of the increased or decreased heat provided by the heater 48). The change in sensor 36 operation and oxygen level signal may accordingly be corrected through increased or decreased operation of the heater 48.

CLAIMS

1. An exhaust gas sensor system for an internal combustion engine (22) having an exhaust conduit (30) and a catalytic converter (32) on said conduit, said system comprising, in combination:

an upstream exhaust gas oxygen sensor (38), on said exhaust conduit (30) upstream of said converter (32), for providing an upstream oxygen level signal;

a downstream exhaust gas oxygen sensor (36), on said exhaust conduit (30) downstream of said converter (32), for providing a downstream oxygen level signal; and

a controller (40) for receiving said upstream and downstream sensor oxygen level signals and responsively providing a controlled signal, whereby said controlled signal may be used by said engine to adjust operating parameters.

2. An apparatus as claimed in claim 1 further comprising:

a temperature sensor for detecting a temperature of said downstream sensor and responsively issuing a temperature level signal;

a heater for warming said downstream exhaust gas oxygen sensor; and

a heater control for receiving said temperature level signal, comparing said detected temperature to a predetermined standard, and responsively issuing an activation signal to said heater when said detected temperature differs from said predetermined standard.

3. An apparatus as claimed in claim 2 wherein, upon receiving dynamic signals from said upstream and downstream sensors, said controller substantially relies upon said upstream oxygen level signal to provide said controlled signal, and, upon receiving steady state signals from said upstream and downstream sensors, said controller substantially relies upon said downstream oxygen level

signal to provide said controlled signal.

4. An apparatus as claimed in claim 1 wherein said activation signal provided by said heater control is a duty cycle signal that increases the proportion of time that said heater is on as said measured temperature varies more widely from said predetermined standard.

5. An exhaust gas sensor system for an internal combustion engine having an exhaust conduit and a catalytic converter on said conduit, said system comprising, in combination:

an upstream exhaust gas oxygen sensor, on said exhaust conduit upstream of said converter, for providing an upstream oxygen level signal;

a downstream exhaust gas oxygen sensor, on said exhaust conduit downstream of said converter, for providing a downstream oxygen level signal;

an upstream heater for warming said upstream exhaust gas oxygen sensor;

a downstream heater for warming said downstream exhaust gas oxygen sensor;

a temperature sensor, adjacent said downstream exhaust gas oxygen sensor, for detecting a temperature of said downstream sensor and responsibly issuing a temperature level signal;

a heater control for receiving said temperature level signal, responsively comparing said detected temperature to a predetermined standard, and responsively issuing an duty cycle signal to said heater when said temperature differs from said predetermined standard, said duty cycle signal increasing the proportion of time that said downstream heater is on as said measured temperature varies more widely from said predetermined standard; and

a controller for receiving said upstream and downstream sensor oxygen level signals and responsively providing a controlled signal, said controller relying upon said upstream sensor signal to provide said controlled signal upon receiving dynamic signals from said upstream and downstream sensors, and said controller relying upon said downstream sensor signal to provide said controlled signal upon receiving steady state signals from said upstream and downstream sensors.

6. A process for providing an oxygen level signal to a fuel delivery system for an internal combustion engine, said internal combustion engine including a catalytic converter on an exhaust conduit, comprising the steps of:

detecting a downstream oxygen level downstream of said catalytic converter;

detecting an upstream oxygen level upstream of said catalytic converter; and

providing a controlled signal to said fuel delivery system based upon said upstream and downstream oxygen levels

7. A process for providing an oxygen level signal as claimed in claim 6 wherein said downstream oxygen level is detected with an oxygen sensor adjacent a heater, said process further comprising the steps of:

sensing the temperature downstream of the catalytic converter;

comparing the downstream temperature with a predetermined standard; and

activating said heater when said temperature is substantially below said predetermined standard.

8. A process as claimed in claim 7 further comprising the steps of issuing a controlled signal related to said upstream oxygen level, when said upstream and downstream oxygen levels are substantially changing, and issuing a controlled signal related to said downstream oxygen level, when said upstream and downstream oxygen levels have substantially reached steady state.

9. A process as claimed in claim 8 wherein said step of activating said heater comprises the steps of

activating said heater for a first predetermined period of time and deactivating said heater for a second predetermined period of time, said first predetermined period of time increasing with respect to said second predetermined period of time as said temperature downstream of said catalytic converter decreases with respect to said predetermined standard.

Patents Act 1977
Examiner's report to the Comptroller under Section 17
(The Search report)

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Relevant Technical Fields

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(ii) Int Cl (Ed.5) F02D 41/14; G01N

Search Examiner
D J MOBBS

Date of completion of Search
24 JANUARY 1994

Databases (see below)
(i) UK Patent Office collections of GB, EP, WO and US patent specifications.

(ii)

Documents considered relevant following a search in respect of Claims :-
1-9

Categories of documents

X: Document indicating lack of novelty or of inventive step.

Y: Document indicating lack of inventive step if combined with one or more other documents of the same category.

A: Document indicating technological background and/or state of the art.

P: Document published on or after the declared priority date but before the filing date of the present application.

E: Patent document published on or after, but with priority date earlier than, the filing date of the present application.

&: Member of the same patent family; corresponding document.

Category	Identity of document and relevant passages		Relevant to claim(s)
X,Y	GB 2257546 A	(FORD MOTOR CO)	X:1,6 Y:2,4,7
X,Y	WO 90/05240 A1	(BOSCH)	X:1,6 Y:2,4,7
Y	EP 0482366 A2	(MITSUBISHI)	2,7
Y	US 5148795	(TOYOTA)	2,7
X,Y	US 5101625	(NIPPONDENSO)	X:1,6 Y:2,4,7
X,Y	US 4745741	(TOYOTA)	X:1,6 Y:2,4,7
Y	US 4655182	(TOYOTA) see particularly column 10 lines 56-60	4

Databases: The UK Patent Office database comprises classified collections of GB, EP, WO and US patent specifications as outlined periodically in the Official Journal (Patents). The on-line databases considered for search are also listed periodically in the Official Journal (Patents).